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Losses from Shrinkage and Quality Deterioration of

CORN STORED IN COUNTRY ELEVATORS

AND AT BIN SITES IN IOWA

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April 1957

LOSSES FROM SHRINKAGE AND QUALITY DETERIORATION OF CORN STORED IN COUNTRY ELEVATORS AND AT BIN SITES IN IOWA

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SUMMARY

Corn storage costs include losses in market value attributable to physical changes in corn while it is in storage. In this study, these losses were determined by measuring changes in weights and grade of corn which was stored at country elevators and at bin sites[1] over an extended storage period.

A loss of 3.74 cents per bushel in market value of 1948, 1949 and 1950 CCC-owned corn stored in country elevators for slightly more than 2-1/2 years (2.71) was attributed to deterioration in quality and shrinkage from moisture loss during the time the corn was stored. This averaged 1.39 cents per bushel on an annual basis. Of this amount about 40 percent (0.56 cent) was attributed to shrinkage and 60 percent (0.81 cent) to deterioration in quality.

A loss of 5.77 cents per bushel in market value of "old" corn stored at bin sites for about three years (2.91 years) was attributed to deterioration in quality and shrinkage during the time the corn was stored. On an annual basis, this averaged 2 cents (1.99 cents) per bushel stored. Of this amount, 38 percent (0.76 cent) was attributed to shrinkage loss and 62 percent (1.23 cents) to deterioration in quality.

Storage records for corn owned by the Commodity Credit Corporation which was produced in 1948, 1949, and 1950 provided basic data for the study. Complete information was obtained on the quantity of corn which was received, shipped out, or on hand; the dates of receipt and shipments; and weights and grade factors for corn when received and shipped out of storage. Some data also were obtained for CCC-owned corn from a more recent crop (1952) which had been moved out of storage. However, it is doubtful if the first 1952 corn moved out of storage represents the total of such corn. The 1948, 1949 and 1950 crops are the latest crops which have been completely moved out of storage and for which the data are assured by representative samples.

Shrinkage loss was determined from the difference between total bushels received for storage and total bushels moved out at the end of the storage period. The weighted average market value used in determining the cost of shrinkage loss at elevators was $1.44 a bushel. For comparative purposes, $1.44 was also used to determine the total value of shrinkage losses at bin sites.

Deterioration in quality of corn while in storage was the difference between the total quality discount on corn when shipped from storage and total quality discount when received into storage. Conclusions regarding loss in market value of stored corn are presented separately for elevators and bin sites; no direct comparison between the two types of facilities are offered.

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[1] Bin sites are collection points at which Commodity Credit Corporation has erected bins for storing corn acquired in connection with price support programs.

A total of 4,952,727 bushels of corn from the 1948, 1949, and 1950 crops was received in 40 country elevators making up the sample for study, and 4,905,370 bushels were shipped out. The total amount of shrinkage was 52,357 bushels, or slightly more than 1 percent (1.05) of the total bushels received. On an annual basis, shrinkage amounted to about two-fifths of 1 percent (0.30) per bushel stored.

The cost of shrinkage in reserve stocks of "old" corn was established at 0.56 cent per bushel year of corn stored. Loss from shrinkage per bushel year averaged 0.45 cent for the concrete and wood elevators. It was higher for steel tanks at 0.68 cent per bushel year, and highest for flat steel structures at 1.29 cents per bushel year.

The net loss from deterioration in quality per bushel year was greater than the shrinkage loss. It averaged 0.81 cent for the 40 sample elevators. Loss from deterioration in quality for the 4 structure groups averaged least for wood elevators at 0.32 cent per bushel year and was next highest for concrete elevators at 0.92 cent. It averaged slightly over 1 cent for steel tanks and flat steel buildings (1.04 and 1.10 cents, respectively).

An index of storage management practices was compiled to aid in determining the degree to which certain management practices were accepted and statistical analysis was used to measure the relationship between loss in market value from shrinkage plus quality deterioration and the following three factors: management of the corn in storage, length of storage period, and number of bushels stored.

Quantitatively, it was established that:

(1) An increase of one month in the storage period was associated with a decrease of about 0.08 cent in the total annual per bushel loss in market value;

(2) An increase of 500,000 bushels in the amount of corn stored was associated with an increase of about 0.5 cent in the total annual per bushel loss in market value; and

(3) An increase of 5 points in the management index was associated with a decrease of about 0.3 cent in the total annual per bushel loss in market value.

Based upon data available, 21 of the sample elevators shipped out a total of 1,024,195 bushels of 1952 CCC-owned corn. This corn had been held an average of 20 months. The total cost of quality deterioration and shrinkage averaged 1.65 cents per bushel shipped, or 1 cent per bushel year of storage. The cost of shrinkage averaged 0.73 cent per bushel year of storage. The cost of quality deterioration made up the remainder--0.27 cent per bushel year of storage.

A total of 18,314,390 bushels of 1948, 1949, and 1950 corn was received into storage at the 95 sample bin sites, and 18,033,722 bushels were moved out or were on hand at the time the study was completed. The total shrinkage during the complete storage period was 280,668 bushels or 1.53 percent of the total quantity received. This amounted to about one-half of 1 percent (0.53 cent) per bushel year of corn stored.

Deterioration in quality of corn stored averaged 0.1 cent per bushel received into storage, or 0.03 cent per bushel per year of storage for the 10 sample counties.

The statistical analysis which measured relationships of the loss in market value during storage to the management index, the length of storage period, and the size of the bin site revealed that:

Quantitatively, the total annual per bushel cost of shrinkage plus quality deterioration

(1) increased about 0.2 cent with each increase of 5 points in the management index,

(2) decreased by about 0.1 cent with each 3-month increase in length of the storage period, and

(3) increased by about 0.25 cent with each 1,000,000-bushel increase in the number of bushels of corn stored at the bin sites.

The total dollar loss in market value of the 2,041,359 bushels of 1952 corn moved out of the sample bin sites was $46,832, or 2.29 cents per bushel. Some of this was bin tops and other heavily deteriorated corn sold locally.[2] A total of 1,832,200 bushels was moved out under loading order, on which the total dollar deterioration was $26,668.98. This amounted to 1.5 cents per bushel shipped. The average storage period was less than a year (10.6 months) for the corn shipped out.

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[2] Under present legislation it is impossible to move sound 1952 corn out of storage at market prices below a formula price (based on the support price) unless the corn is out of condition, or threatens to go out of condition. Because of this, the 1952 corn moved up to the time of the study was probably not representative of all corn stored with respect to quality deterioration incurred.

INTRODUCTION

The study on which this report is based developed from the needs of corn producers, elevator managers, and public and private agencies concerned with storage problems in the extent of loss in market value due to shrinkage and quality deterioration of corn stored over an extended storage period. The U. S. Department of Agriculture, which is directly interested in such losses because of the large quantity of corn acquired under the price support program, initiated a study of loss in market value, as related to changes in weights and grades of stored corn, at several storage positions. This report makes findings of the study available to all concerned with corn storage operations.

There is considerable uncertainty about the extent of losses due to physical changes in stored corn. Customarily, corn has been used in the year following harvest and only relatively small quantities have been stockpiled. For this reason, very little information has been available on the extent of shrinkage from moisture loss of deterioration in quality of stored corn over longer periods of time. However, because of recent accumulations, some corn has been held at one location for periods of several years. Most such reserve stocks are owned by Commodity Credit Corporation.

Corn which is owned by CCC has been delivered to the Government by producers who obtained a loan or purchase agreement on corn stored on their farms in connection with price support programs, and who, at maturity date, elected to turn over to CCC a stated quantity of eligible corn in settlement of their contracts. The Government must provide storage space for such corn until the corn can be sold without depressing prevailing market prices. Most of it is stored at Government collection points (bin sites) or at commercial elevators or similar facilities. The bin sites are areas leased for the purpose of CCC on which it has erected storage bins.

Records on receipts and outshipment of all CCC-owned corn are maintained by the Government so that comparable data are available on corn, whether it is stored in elevators, at bin sites, or on farms.[3] The U. S. Department of Agriculture contracted with the Iowa Agricultural Experiment Station, Ames, Iowa, to review these storage records for the purpose of evaluating costs related to shrinkage and quality changes. The Experiment Station conducted the survey late in 1954 and early in 1955, examining records of a sample of country elevators and Government bin sites in Iowa.

Corn produced in 1948, 1949, and 1950 had been held in storage at elevators and bin sites for various lengths of time. Complete data were available on the quantity of the "old" corn received, shipped out, or on hand, together with dates of receipt and shipment. Weights and grade factors were also on record for corn when received and shipped out of storage. These data provided the primary basis for the study and the findings here. For comparative purposes, similar data were obtained for corn from a recent crop (1952) which had been moved out of storage. Most of the 1952 corn was still in storage at the time the study was made so that complete information could not be obtained. A direct comparison of losses between the two groups is not made in this report because it is assumed that the part of the 1952 crop which was moved out of storage early in the storage period would not necessarily be representative of all stored corn.

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[3] Corn on which CCC has made a loan may be held on farms beyond the first storage year under certain conditions. If there is insufficient space in elevators and at bin sites to store the quantities of a commodity delivered to CCC, and if climatic conditions are such that the commodity may be stored safely on farms for another year, the Government may announce an extended-storage "reseal" program in which the producer may extend his original loan and reseal grain on his farm for an additional year in lieu of delivering it to CCC or of repaying his loan. He receives a storage payment for each additional year's storage under the reseal program.

This report presents, both for elevators and bin sites, information on the extent and value of losses due to shrinkage from moisture loss and deterioration in quality of stored corn. A study on loss in market value due to physical changes in corn stored on farms under a reseal program was made as a companion to this study on losses at elevators and bin sites.[4]

Relationship between the loss in market value of stored corn and several factors which were expected to affect such loss were analyzed statistically. It was assumed that loss in market value might depend, at least in part, on the number of months the corn was in storage, the size of the storage facility, and the management of the corn in storage. Data for the first two factors were obtained from storage records but an index was designed by the authors to describe the measure storage management practices. Storage management schedules were obtained for the sample bin sites and elevators and responses were used to set up a management index score for each. The index was prepared as an experiment in quantitative analysis of storage management practices.

It is a device to determine the management practices most commonly used, the degree to which their acceptance varies among storage operators, and the relationship such management practices have to costs incurred in losses from shrinkage and quality deterioration. The authors recognize that the areas studied and values assigned to their importance are subjective and that further study is needed before a conclusive index is obtained.

COUNTRY ELEVATORS

Population and sample

The country elevators used in this study were the same ones used in a previous study of the costs of storing corn at country elevators.[5] They were a stratified random sample of the bonded country warehouses in Iowa having modern facilities.

On December 31, 1951, there were 799 bonded grain warehouses in Iowa. Approximately 650 of this group were country elevators which normally store grain for producers and for the Government under the price support program. For purposes of this survey, 163 of these 650 elevators were selected by eliminating those which had not constructed bulk grain storage space in recent years, and those which did not have a bulk grain licensed capacity of 40,000 bushels or more. Small elevators were excluded to eliminate those where commercial storage is a very minor part of the total operation. The remaining elevators consisted of cooperative, independent and line houses in proportions quite typical of the entire 650.

The elevators were divided by type of construction into three groups--concrete, wood and steel. Concrete elevators for the most part are complete units with headhouse and tanks built into one structure, although in some cases an ironclad wood crib elevator is operated as a supplement to the concrete structure. The wood elevators generally consist of an older elevator and a new annex, also of wood construction and clad with corrugated iron.

Elevators in the steel construction classification are of two types. Some are basically wood crib elevators with added storage space of Quonset-type or other flat steel construction. Others consist of large, bolted steel tanks which are so situated and equipped that they can be served from the elevator headhouse. Usually, these tanks have been built around an older wood crib elevator but, in a few cases, they are combined with a new steel beam headhouse to form a complete unit.

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[4] Losses from Quality Deterioration and Shrinkage of Corn Resealed on Iowa Farms. AMS-166, Agr. Mkrt. Serv., U. S. Dept. Agr., March 1957.

[5] Dachtler, W. C., et al. Costs of Storing Reserve Stocks of Corn. Mktg. Res. Rept. 93, Agr. Mktg. Serv., U. S. Dept. Agr., June 1955.

The elevators in the group studied were divided into groups according to their capacity (table 1). In the case of steel and wood elevators, the lowest capacity group was subdivided into licensed capacities from 40,000 to 60,000 bushels, and over 60,000 but under 90,000 bushels. As is shown in the table, the original study consisted of 44 elevators. The sample elevators were selected at random within structure types and licensed capacity strata.

Table 1.--Population and sample of country elevators having more than 40,000 bushels storage capacity and with some construction since 1946

Type of storage construction	Licensed storage capacity (1,000 bushels)							
	40-60	40-89	61-89	90-159	160-259	260-385	Over 385	Total
Population:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Concrete.........	--	5	--	8	8	12	2	35
Steel............	22	--	14	15	3	6	0	60
Wood.............	21	--	22	20	4	1	0	68
Total.........		84		43	15	19	2	163
Sample:								
Concrete.........	--	2	--	3	3	4	1	13
Steel............	6	--	4	3	1	2	0	16
Wood.............	4	--	4	4	2	1	0	15
Total.........		20		10	6	7	1	44

Forty of the 44 sample elevators in the previous study had held 1948, 1949 and/or 1950 CCC-owned corn in storage. These 40 Iowa country elevators comprised the group for the study of quality deterioration and shrinkage in the 1948, 1949, and 1950 corn. There were 13 concrete elevators, 13 wood elevators and 14 steel elevators in the sample.

All 44 of the original sample elevators had held 1952 CCC-owned corn in storage and were included in the sample for the study of quality deterioration and shrinkage of 1952 elevator-stored corn. However, only 21 of the 44 had shipped any of their 1952 corn out of storage at the time the study was completed. The 21 included 11 concrete elevators, 4 wood elevators, and 6 steel elevators.

Method of obtaining data

Data on quantities of corn received into and shipped from the elevators were obtained from the storage settlement sheets in the Chicago Office of the Commodity Stabilization Service and were verified from elevator records. In all cases, the extent of shrinkage and quality deterioration was determined by comparing weights and grade factors of incoming corn with weights and grade factors of outgoing corn. Warehouse receipt weights and grades were used for incoming data. Destination weights and grade factors were used for outgoing data.

Price and discount data used to establish the market value of corn shrinkage were those used by the Chicago CSS Commodity Office in computing settlement with each elevator as of the date of billing the final car in each loading order. The discount rates used for shipments from storage were also used for computing quality discounts on corn receipts into elevator storage.

CCC-owned corn may be stored on a co-mingle basis, making it possible for a warehouseman to substitute other corn so long as he maintains quality and quantity to protect warehouse receipts for CCC corn. In the few cases where grain was actually co-mingled, elevator records were carefully checked to measure the substitution made. This substitution was taken into account in figuring the quality deterioration and shrinkage incurred in the CCC-owned corn.

Length of Storage and Storage Volume

The average number of years the "old" (1948, 1949, 1950) CCC corn was in storage in elevators of each structure type varied from 2.57 years for the flat steel elevators to 2.84 years for the wood elevators. The over-all average storage period for the 40 elevators was 2.71 years. (See table 2.) The dates of the first and last receipts and the first and last shipments in each of the structural groups are shown below.

Table 2.--Average storage period and dates of receipts and shipments of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators, by structure type

Type of structure	Average years in storage	Date of		Date of	
		First receipt (mo. yr.)	Last receipt (mo. yr.)	First shipment (mo. yr.)	Last shipment (mo. yr.)
Concrete.........	2.67	8 - 49	10 - 50	11 - 49	2 - 54
Wood.............	2.84	8 - 49	9 - 51	9 - 50	8 - 53
Steel tank.......	2.78	8 - 49	9 - 51	9 - 50	8 - 54
Flat steel.......	2.57	8 - 49	9 - 51	9 - 51	12 - 53
All elevators....	2.71	8 - 49	9 - 51	11 - 49	8 - 54

The average number of years in storage and the dates of first and last receipt and first and last shipment of the "old" corn varied somewhat more among the individual sample elevators. The average storage period varied from 1.45 years for concrete elevator number 8, to 3.58 years for wood elevator number 45. The average storage period was less than two years in 5 of the elevators, and more than three years in 7 of them. Most of the elevators received their first corn for storage in August or September, 1949, and their last corn for storage in September or October, 1949, so that most of the CCC-owned corn under study was produced in 1948. Sixteen of the elevators received their last of this corn in 1950, 6 received their last in 1951, and only 1 received any of the "old" corn in 1952. Most of the corn was shipped out during 1952 and 1953, but some shipment was made as early as November 1949, from concrete elevator number 10, and as late as August 1954 from steel tank elevator number 27.

The average bushel years the corn was in storage for elevators of each type of structure was obtained by multiplying the bushels of corn received by the length of the storage period (in years). The average bushel years of storage varied from 158,928 for the flat steel elevators, to 584,011 for the concrete elevators and averaged 335,514 for all 40 of the sample elevators (table 3).

For the individual elevators, the bushel years of storage varied from 24,406 for one of the wood elevators, to 2,032,954 for one of the concrete elevators. The total bushels of storage was under 100,000 for 10 of the elevators. Only 1 elevator had over 1,000,000 bushel years of storage. Nine of the elevators had between 500,000 and 1,000,000 bushel years of storage.

The total volume of corn received for storage at sample country elevators was 4,952,727 bushels, and the average was 123,943 bushels per elevator (table 4). There was considerable difference in storage volume by structure type, with the average ranging from 218,723 bushels for concrete elevators to 61,774 bushels for flat steel structures.

Table 3.--Bushel years of 1948, 1949, and 1950 corn stored in 40 Iowa country Elevators

Type of structure	Number of elevators	Bushel years of corn stored	
		Total	Per elevator
		Bushels	*Bushels*
Concrete..............	13	7,592,143	584,011
Wood..................	13	3,102,793	238,676
Steel tank............	5	1,295,262	259,052
Flat steel............	9	1,430,349	158,928
All elevators.........	40	13,420,547	335,514

Table 4.--Shrinkage of reserve stocks of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators by type of structure

Type of structure	Number of elevators	Quantity of corn received		Quantity of corn shipped		Shrinkage		Shrinkage as % of bushels received	Shrinkage as % of bushel years stored
		Total	Average per elevator	Total	Average per elevator	Total	Average per elevator		
		Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Percent*	*Percent*
Concrete...........	13	2,843,397	218,723	2,819,779	216,906	23,618	1,817	0.83	0.31
Wood...............	13	1,092,142	84,011	1,082,298	83,253	9,844	757	0.90	0.32
Steel tank.........	5	466,224	92,245	460,046	92,009	6,178	1,236	1.33	0.48
Flat steel.........	9	555,964	61,774	543,247	60,361	12,717	1,413	2.29	0.88
All elevators......	40	4,952,727	123,943	4,905,370	122,634	52,357	1,309	1.05	0.39

The corresponding total and average volumes of corn moved out of storage are also shown in table 4. These figures represent the actual volume, by weight, of 1948, 1949, and 1950 corn loaded out of storage. They do not include bin tops or other completely deteriorated corn left out of the car when filling a loading order. The average volume shipped from the 40 elevators was 122,634 bushels per elevator.

Shrinkage

Physical shrinkage over the entire storage period is represented by the difference between the total bushels received for storage and the total bushels moved out of storage. The average shrinkage per elevator was 1,309 bushels but varied from 757 bushels for the wood elevators, to 1,817 bushels for the concrete elevators (table 4). Percentagewise, the weighted average shrinkage per bushel received over the entire storage period of 2.71 years varied from 0.83 percent for the concrete elevators, to 2.29 percent for flat steel elevators. The overall weighted average shrinkage per bushel was about 1 percent (1.05).

The weighted average shrinkage, per bushel per year, was 0.39 percent for 40 elevators. It was about the same for concrete and wood elevators (0.31 and 0.32 percent, respectively), about one-half percent (0.48) for steel tank storage and highest for flat steel buildings (0.88).

The figure used for the value per bushel of corn lost through shrinkage was that determined for each elevator by Commodity Credit Corporation on the basis of the market value of the corn the day it was shipped. The weighted average value per bushel of shrinkage varied from $1.41 for the wood elevators, to $1.45 for the flat steel elevators (table 5). The over-all weighted average was $1.44 per bushel.[6] The average dollar value of shrinkage per elevator was lowest for wood elevators, $1,071, and highest for concrete elevators, $2,621. It amounted to $1,879 for all 40 elevators.

Table 5.--Value of shrinkage in reserve stocks of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators (value of stored corn established at $1.44 per bushel)

Type of structure	Value of shrinkage				
	Total	Per elevator	Per bushel of shrinkage	Per bushel received	Per bushel year of corn stored
	Dollars	*Dollars*	*Dollars*	*Cents*	*Cents*
Concrete..........	34,069	2,621	1.44	1.20	0.45
Wood..............	13,923	1,071	1.41	1.27	0.45
Steel tank.........	8,755	1,751	1.42	1.88	0.68
Flat steel.........	18,411	2,046	1.45	3.31	1.29
All elevators......	75,158	1,879	1.44	1.52	0.56

The physical shrinkage figures for the individual elevators varied from zero for one of the wood elevators and two of the flat steel elevators, to 7,234 bushels for one of the concrete elevators. The shrinkage per bushel of corn received varied from zero for the 3 elevators, to 7.25 per cent for one of the flat steel elevators. Fourteen of the elevators had a shrinkage of less than 1/2 of 1 percent, 9 between 1 and 1-1/2 percent, 4 between 1-1/2 and 2-1/2 percent, 4 between 2-1/2 and 3-1/2 percent, one 4.43 percent, and one 7.25 percent. The shrinkage per bushel year of storage varied from zero for the 3 elevators to as high as 4.28 percent for one of the flat steel elevators. Eleven of the elevators had a shrinkage of less 0.1 percent per bushel year of storage, 7 between 0.1 percent and 0.3 percent, 9 between 0.3 and 0.5 percent, 8 between 0.5 and 1 percent, 4 between 1 and 2 percent, and the 1 a shrinkage of 4.28 percent per bushel year of storage.

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[6] These weighted averages were obtained by dividing the total dollar shrinkage figures shown in the second column of table 5 by the total bushels of shrinkage shown in the seventh column of table 4.

Over the entire storage period, the weighted average value of shrinkage per bushel received into storage varied from 1.2 cents for the concrete elevators to 3.31 cents for the flat steel elevators (table 5). The over-all weighted average was just over one and one-half cents (1.52). The weighted average value of shrinkage per bushel year of storage, varied from 0.45 cent for both the concrete elevators and the wood elevators to 1.29 cents for the flat steel elevators. The over-all weighted average was just over a half cent (0.56) per bushel year of storage.

The total dollar loss in market value due to shrinkage varied from zero for 3 elevators to $10,521 for the one concrete elevator. The average value of the shrinkage per bushel for the 37 elevators which incurred shrinkage varied from 62 cents for one of the concrete elevators to $2.25 for one of the wood elevators. The value of shrinkage per bushel received varied from zero for the 3 elevators to 10.42 cents for the one flat steel elevator. This value was less than 0.2 cent for 9 of the elevators, between 0.2 and 0.5 cent for 4, between 0.5 cent and 1 cent for 3, between 1 and 2 cents for 12, between 2 and 3 cents for 4, between 3 and 4 cents for 4, between 4 and 5 cents for 1, between 5 and 6 cents for 2, and 10.42 cents for the one elevator. The value of the shrinkage per bushel year of storage varied from zero for the 3 elevators to 6.15 cents for one elevator. This value was less than 0.1 cent for 8 of the elevators, between 0.1 and 0.2 cent for 5, between 0.2 and 0.5 cent for 7, between 0.5 and 1 cent for 12, between 1 and 2 cents for 6, between 2 and 3 cents for 1, and 6.15 cents for the one elevator.

Quality deterioration

The net value of quality deterioration of corn while in storage was lowest for wood elevators at $771 per elevator (table 6). (See page 7 for methods of computing these discounts). It was $5,377 for the concrete elevators, $2,681 for steel tank storage, and $1,754 for flat steel buildings. The over-all average net value of quality deterioration per elevator was $2,728.

Table 6.--Deterioration in reserve stocks of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators

Type of structure	Total discounts on				Net value of deterioration of corn while in storage	
	Corn shipped		Corn received			
	Total	Per elevator	Total	Per elevator	Total	Average per elevator
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Concrete..........	84,737	6,518	14,840	1,142	69,897	5,377
Wood..............	11,357	874	1,334	103	10,023	771
Steel tank........	15,309	3,062	1,902	380	13,407	2,681
Flat steel........	17,026	1,892	1,238	138	15,707	1,754
All elevators.....	128,429	3,211	19,314	483	109,034	2,728

The weighted average discount on corn shipped ranged from 0.37 cent per bushel year of storage for the wood elevators, to 1.19 cents for the flat steel elevators, and came to 0.96 cent for all elevators (table 7). The weighted average discount on corn received varied from 0.04 cent for the wood elevators, to 0.22 cent for the flat steel elevators, and came to 0.14 cent for the entire group.

The weighted average value of deterioration while in storage per bushel year of storage was considerably lower (0.32 cent) for the wood elevators than for the other three types. It was 0.92 cent for concrete elevators, 1.04 cents for steel tanks, and 1.1 cents for flat steel buildings.

Table 7.--Discounts on shipments and receipts and net value of deterioration per bushel year of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators by type of structure

Type of structure	Total bushel years of corn stored	Discounts		Net value of deterioration in storage per bushel year
		On shipments per bushel year stored	On receipts per bushel year stored	
	Bushels	*Cents*	*Cents*	*Cents*
Concrete............	7,592,143	1.12	0.20	0.92
Wood................	3,102,798	0.37	0.04	0.32
Steel tank..........	1,295,262	0.87	0.15	1.04
Flat steel..........	1,430,979	1.19	0.22	1.10
Total...............	13,420,547	0.96	0.14	0.81

The per unit costs of quality deterioration varied even more among the individual sample elevators. The discounts on shipments per bushel received varied from zero for two elevators to 23.12 cents for one of the steel tank elevators. The net value of deterioration while in storage per bushel received varied from a gain of 0.77 cent to a loss of 23.10 cents. The discount on shipments per bushel year of storage varied from zero for the 2 elevators, to 7.93 cents for one of the concrete elevators. The discount on receipts per bushel year of storage varied from zero for 9 of the elevators, to 3.21 cents for elevator number 8. The total net deterioration per bushel year of storage varied from plus 0.26 cent to 7.84 cents. Two of the elevators had a gain in market value while the corn was in storage, and one had neither a gain nor a loss. Seven of the elevators had a loss in market value of 0.1 cent or less per bushel year of storage. For 12 this cost was between 0.1 and 0.5 cent, for 10 between 0.5 and 1.0 cent, for 2 between 1.0 and 1.5 cents, for 4 between 3 and 5 cents, and for 2 over 6.5 cents.

Total decrease in value of stored corn

The total decrease in value of 1948, 1949, and 1950 corn due to shrinkage and deterioration is summarized in table 8. The total net loss in market value of corn due to these factors while in storage varied from an average of $1,842 per elevator for the wood elevators to an average of $7,997 for the concrete elevators. The over-all average was $4,607. The weighted average total loss in market value from these causes, per bushel received, varied from 2.19 cents for the wood elevators to 6.15 cents for the flat steel elevators, and amounted to 3.74 cents for all groups. The weighted average total of these losses in value, per bushel per year of storage, was lowest for the wood elevators (0.77 cent) and next lower for concrete elevators at 1.37 cents, and steel tanks at 1.71 cents. Loss was highest for flat steel buildings at 2.39 cents per bushel per year of storage. The loss for corn stored in all sample elevators averaged 1.39 cents per bushel year.

The total loss in market value owing to shrinkage and deterioration during storage varied among the individual elevators from zero for one of the wood elevators to $22,601 for one of the concrete elevators. The total decrease from these causes in market value per bushel received varied from zero to 24.14 cents for one of the steel tank elevators. This loss amounted to less than 1 cent per bushel received for 6 of the elevators, between 1 and 2 cents for 9, between 2 and 3 cents for 7, between 3 and 4 cents for 4, between 4 and 5 cents for 4, between 5 and 10 cents for 5, and over 10 cents for 5 of the sample elevators. The total decrease in market value per bushel year of storage owing to shrinkage and deterioration varied from zero to 10.24 cents for one of the flat steel elevators. This decrease in value per bushel year of storage amounted to less than 0.5 cent for 9 of the elevators, between 0.5 and 1.0 cent for 10, between 1 and 2 cents for 11, between 2 and 3 cents for 4, between 4 and 5 cents for 2, and over 6 cents for 4 of the sample elevators.

Table 8.--Net value of deterioration and value of shrinkage of 1948, 1949, and 1950 corn stored in 40 Iowa country elevators, by type of structure

Type of structure	Net value of deterioration	Value of shrinkage	Net value of deterioration plus shrinkage			
			Total	Per elevator	Per bushel received	Per bushel year stored
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Cents*	*Cents*
Concrete.........	69,897	34,069	103,966	7,997	4.66	1.37
Wood.............	10,023	13,923	23,946	1,842	2.19	0.77
Steel tank.......	13,407	8,755	22,162	4,432	4.75	1.71
Flat steel.......	15,787	18,411	34,198	3,800	6.15	2.39
All elevators....	109,114	75,158	184,272	4,607	3.74	1.39

Costs of quality deterioration and shrinkage per bushel year of storage related to management index, length of storage and bushels stored

The loss in market value of CCC-owned corn during storage at country elevators due to both shrinkage and quality deterioration might reasonably be expected to depend in part on the management[7] of the corn in storage, the length of the storage period, and the number of bushels stored. Considerable variation was observed among the records obtained from the forty elevators with respect to these three factors, as well as with respect to the annual per bushel loss in market value during storage. The relationship between these factors and the loss in market value was measured by multiple regression analysis.

Two different linear multiple regression equations were used. In one, the observed total annual per bushel loss in market value from shrinkage plus quality deterioration was taken as a function of the observed management index, length of storage and bushels of corn stored in each of the 40 elevators. This equation explained 41 percent of the variation in the observed total annual per bushel loss in market value, and the results were statistically significant at the .01 probability level. In the second equation, the observed annual per bushel loss in market value from shrinkage alone was taken as a function of the same three variables. Twenty-three percent of the variation in the observed cost of shrinkage alone was explained by the variation and the results were statistically significant at the .05 probability level.

In both instances, the total annual per bushel costs were found to vary inversely with the management index score. Quantitatively, an increase of 5 points in the management index score was found to be associated with

(1) a decrease of about three-tenths of a cent in the total annual per bushel loss in market value, and

(2) a decrease of about five-hundredths of a cent in the annual per bushel loss in market value due to shrinkage alone.[8]

Both the total annual per bushel cost of shrinkage plus quality deterioration, and that of shrinkage alone, also were found to vary inversely with the number of months of storage. In the case of the shrinkage costs alone this relationship was found to be statistically significant. This inverse relationship is contrary to the common belief of elevator managers since it indicates that the annual per bushel costs of both shrinkage and quality deterioration decrease as the length of the storage period increases. However, it may not contradict this common belief entirely. Instead, it may have resulted from a situation where the corn which went out of condition first was shipped out early and therefore was stored for a shorter period. In any case, the results obtained seem quite conclusive in the case of shrinkage alone, and definitely indicative in the case of total per year loss in market value during storage.[9] Quantitatively, each additional month of the storage period was found to be associated with

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[7] An index of storage management was compiled to aid in determining the degree to which approved storage management practices have been accepted. This is a subjective analysis and is explained in detail in appendix A.

[8] Statistically, the relationship of both costs to the management index is highly significant.

(1) a decrease of about 0.08 cent in the total annual per bushel loss in market value, and

(2) a decrease of 0.04 cent in the annual per bushel cost of shrinkage alone.

The relationships found between the number of bushels stored and the total annual per bushel loss in market value owing to shrinkage and deterioration, as well as that between the cost factor and the annual per bushel cost of shrinkage alone, were not statistically significant. This total loss in value was found to be positively associated with the quantity stored, while the cost of shrinkage alone was found to be negatively associated with it. Quantitatively, an increase of 500,000 bushels in the amount of corn stored will be associated with

(1) an increase of about 0.5 cent in the total annual per bushel loss in market value, but

(2) a decrease of about 0.08 cent in the cost of shrinkage alone.

Quality deterioration and shrinkage in the 1952 corn

Technology of storage management has advanced since 1948 CCC-owned corn was originally placed in country elevators in Iowa. Mechanical aeration is perhaps the most important single development, but residual insecticides, improved fumigants, methods of controlling incoming quality, and temperature and humidity recording equipment have all been developed substantially since that time. In view of such advancements, one would expect costs of quality deterioration and shrinkage to be less in present long-term storage than that incurred in storing 1948 and 1949 corn.

It is virtually impossible to compare quantitatively the extent of quality deterioration and shrinkage of 1952 CCC-owned corn with that of the "old" corn stored in the elevators. The 1948, 1949, and 1950 crops of CCC-owned corn are the latest crops which have been completely moved out of elevator storage, and for which an assured representative sample could be taken. The figures reported here for the 1952 corn stored in elevators are for the first shipments of such corn from the 44 sample elevators and it is doubtful if the first corn which is moved out is representative of all 1952 corn in elevator storage. Present price support legislation makes it impossible to move sound 1952 corn out of elevators at prices below the formula price except under special circumstances. Such corn must be out-of-condition, or threatening to go out of condition, before it can be moved out. Only 21 of the sample elevators had any such shipments at the time the study was completed.

Subject to these limitations, quality deterioration and shrinkage figures for the first million bushels of 1952 corn moved out of the 21 elevators have been summarized (tables 9 and 10). The quantity shipped varied from 83,513 bushels for the 4 wood elevators to 635,323 bushels for the 11 concrete elevators, and totaled 1,024,195 bushels for the 21 elevators. The corresponding total bushels received into storage varied from 83,308 bushels for the 4 wood elevators to 637,375 bushels for the 11 concrete elevators, and totaled 1,032,780 bushels for the 21 elevators.[10]

The average storage period of the 1952 corn shipped was 20 months. It did not vary greatly for any of the structure groups. The bushel years storage of 1952 corn which was moved out of storage, shown in the seventh column, was obtained by multiplying the total

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[9] Additional analysis is being made of the relationship of costs to quality deterioration alone. This will be the subject of a Ph. D. thesis at Iowa State College by Prof. David N. Harrington, University of Missouri, Columbia, Mo.

[10] It should be pointed out that these figures cannot be considered dependable until an elevator has completed shipment of all its 1952 CCC-owned corn. The warehouse receipts often do not match precisely with the volume of the partially completed shipment.

Table 9.--Total bushels shipped, total shrinkage, total quality discount, and average length of storage of 1952 corn stored in country elevators, by type of structure

Type of structure	Number of elevators in group	Number of elevators with loading orders	Total quantity shipped	Corresponding quantity received	Average length of storage		Total shrinkage	Total loss in market value from		
					Bushel months	Total bushel years		Shrinkage	Quality deterioration	Shrinkage and quality deterioration
			Bushels	*Bushels*	*Months*	*Years*	*Bushels*	*Dollars*	*Dollars*	*Dollars*
Concrete....	14	11	635,323	637,375	21	1,091,782	2,052	2,954.88	2,810.58	5,765.46
Wood........	15	4	83,513	83,308	18	126,010	-205	-295.20	44.21	-250.99
Steel tank..	6	4	153,429	155,692	18	227,808	2,263	3,258.72	333.15	3,591.87
Flat steel..	9	2	151,930	156,405	19	242,786	4,475	6,444.00	1,349.38	7,793.38
Totals....	44	21	1,024,195	1,032,780	20	1,688,386	8,585	12,362.40	4,537.32	16,899.72

Table 10.--Weighted average per unit costs of shrinkage and quality deterioration of 1952 corn stored in country elevators, by type of structure

Type of structure	Cost of shrinkage		Cost of quality deterioration		Cost of shrinkage and quality deterioration	
	Per bushel shipped	Per bushel year of storage	Per bushel shipped	Per bushel year of storage	Per bushel shipped	Per bushel year of storage
	Cents	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
Concrete...........	0.47	0.27	0.44	0.26	0.91	0.53
Wood...............	-0.35	-0.23	0.05	0.03	-0.30	-0.20
Steel tank.........	2.12	1.43	0.22	0.15	2.34	1.58
Flat steel.........	4.24	2.65	0.89	0.56	5.13	3.21
All elevators......	1.21	0.73	0.44	0.27	1.65	1.00

bushels received for each group by the average storage period in years. These figures varied from 126,010 bushel years for the 4 wood elevators to 1,091,782 bushel years for the 11 concrete elevators.

The total bushel shrinkage represents the difference between the corresponding bushels received and the total bushels shipped from the elevators in each group. Although there was a gain of 205 bushels for the 4 wood elevators, the total net shrinkage totaled 8,585 bushels for the 21 elevators. The figures for loss in market value due to shrinkage were obtained by multiplying the total bushel shrinkage for each group by $1.44 per bushel. (This price was used for comparability with the dollar shrinkage figures obtained for the "old" corn stored in the sample elevators.) The loss in market value from quality deterioration of the bushels shipped from elevators varied from $44 for the 4 wood elevators to $2,811 for the 11 concrete elevators, and totaled $4, 537 for the 21 elevators.

The total loss in market value of the corn shipped, which is the simple sum of two previous columns, varied from a gain of $251 for the 4 wood elevators to a loss of $7,793 for the flat steel elevators. It totaled $16,899 for the 1,024,195 bushels shipped from the 21 elevators.

For the individual elevators shipping 1952 corn, the total bushels shipped varied from 2,094 bushels for one of the concrete elevators, to 132,049 bushels for one of the flat steel elevators. The average length of storage for the corn shipped varied from 6 months for one wood elevator to 24 months for 3 of the concrete elevators. The bushel years of storage of the corn shipped varied from 3,664 to 223,415. The individual shrinkage figures varied from a gain of 1,432 bushels for one concrete elevator to a loss of 3,201 bushels for one flat steel elevator. Five of the 21 elevators had a "negative" shrinkage, e.g., a gain in the quantity during the storage period. The loss in market value during storage from shrinkage varied from a gain of $2,062.08 to a loss of $4,609.44. The loss in market value from quality deterioration alone varied from a gain of $248.73 to a loss of $1,349.38. The total loss in market value varied from a gain of $2,089.86 to a loss of $5,958.82.

The weighted average cost of shrinkage (table 10) varied from a minus 0.23 cent (an appreciation in value) for the wood elevator, to 2.65 cents per bushel year of storage for the flat steel elevators. The over-all weighted average for all elevators amounted to 0.73 cent per bushel year of storage.

The weighted average cost of quality deterioration varied from 0.03 cent for the wood elevators to 0.56 cent per bushel year of storage for the flat steel elevators. The over-all weighted average cost of quality deterioration was 0.27 cent per bushel year of storage.

The weighted average total cost of shrinkage and quality deterioration combined varied from minus 0.2 cent per bushel year of storage for the wood elevators to 3.21 cents per bushel year of storage for flat steel buildings. The weighted average total loss in market value of the 1952 corn for all elevators was 1.65 cents per bushel shipped, or 1.0 cent per bushel year of storage.

The per unit cost of shrinkage of the 1952 corn varied among the individual elevators from a minus 3.91 cents per bushel shipped and a minus 3.60 per bushel year of storage to 10.26 cents per bushel shipped and 9.47 cents per bushel year of storage. The per unit cost of quality deterioration varied from a minus 0.46 cent per bushel shipped and a minus 0.48 cent per bushel year of storage to 3.08 cents per bushel shipped and 1.76 cents per bushel year of storage. The per unit total loss in market value varied from a minus 3.96 cents per bushel shipped and a minus 3.65 cents per bushel year of storage to 10.26 cents per bushel shipped and 9.47 cents per bushel year of storage.

BIN SITES

Population and sample

Supervision, management, and record keeping of bin site storage operations are maintained on a county basis rather than by individual bin sites. Therefore, the population was the 100 county Agricultural Stabilization and Conservation offices in Iowa, each one including all the bin sites under its jurisdiction.

The sample consisted of one county selected at random in each of the 10 then-existing ASC districts in Iowa. These counties were the same as those used as the sample in an earlier study of the costs of storing corn at Government collection points.[11] The sample placed emphasis on the relative importance of corn from one area of the State to another and assured a substantial range among the sample counties in volume of corn stored. The ten districts are shown in figure 1. The shaded county in each district is the sample county.

The 100 county offices in Iowa managed about 1,000 bin sites having a total rated storage capacity of approximately 170 million bushels on January 1, 1952. There were 95 bin sites in the sample counties, which is about 10 percent of the total number of Iowa bin sites.

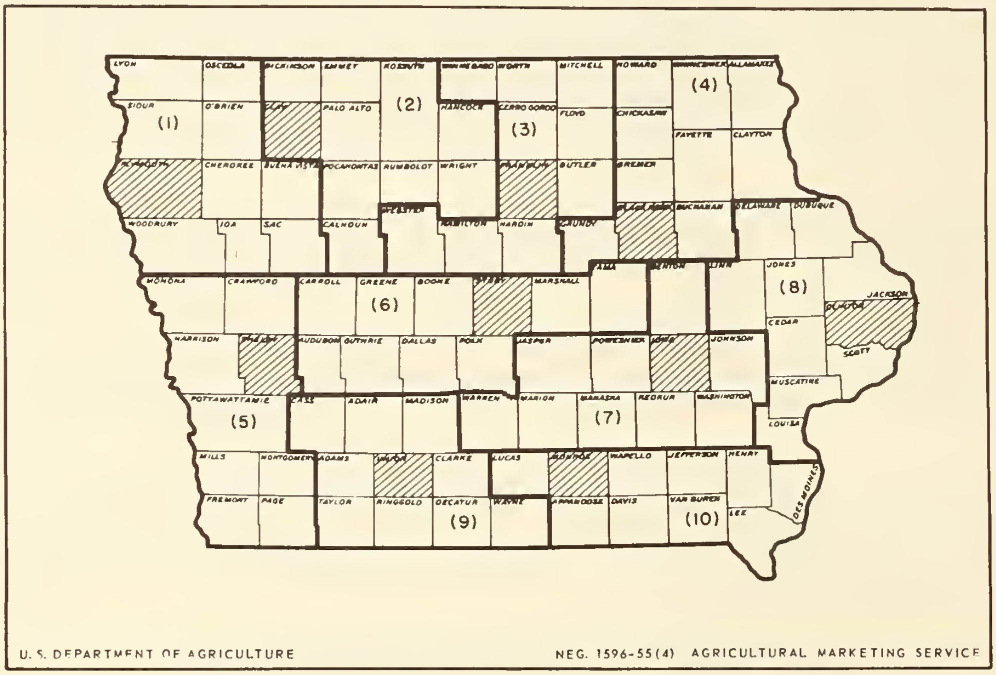

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Figure 1. --Ten ASC districts in Iowa. These counties were used as samples to study loss in market value due to shrinkage and deterioration in quality of stored corn.

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[11] Dachtler, W. C., et al, Costs of Storing Reserve Stocks of Corn, Marketing Research Report No. 93, Agricultural Marketing Service, USDA, June 1955. Use of the same sample in both studies facilitates a cost study being made by Prof. David N. Harrington, University of Missouri, in which costs of storage will be integrated with losses due to shrinkage and quality deterioration of corn stored at bin sites in the 10 counties.

The number of bin sites in each of the 10 sample counties is as follows:

County number	Number of bin sites	County number	Number of bin sites
1	11	6	20
2	10	7	7
3	15	8	4
4	9	9	6
5	10	10	3

Methods of obtaining information

Most of the bin site data were obtained from various record forms of grain receipts into and shipment from the bin sites in the ASC county offices, supplemented by records from the Iowa State ASC Office and the Chicago CSS Commodity Office. Shrinkage and quality deterioration were determined from a comparison of incoming weights and grade factors with outgoing weights and grade factors. Farm producer delivery settlement weights and grades were used for the incoming data. Outgoing weights and grade factors (or prices) were obtained from the official form (No. 102) for bin sites.

Discount rates

The discount rates used for each shipment were averages based upon a series of scales used by CCC in settling with elevators over the period of the shipment from bin sites. On percent of damaged kernels the discounts used were as follows:

Percent damage		Cents per bushel discount	Percent damage		Cents per bushel discount
Over	Up to		Over	Up to	
5	7	1	13	14	5.5
7	8	2	14	15	6
8	9	3	15	16	6.5
9	11	4	16	19	7
11	12	4.5	19	30	8
12	13	5	Over 30--additional 0.5 cent for each additional 1 percent damage.		

Foreign Material discount

The foreign material discount used was one cent for each 1 percent foreign material over 3 percent. The discounts for special grade designation were: (1) musty--1 cent except where mustiness occurs, the total discount is not less than 2 cents; (2) weevily--2 cents; (3) sour--3 cents. Each of these factor discounts was used where applicable on the grade factors both at the time the corn was put into the bin site and at the time it was taken out of the bin site. The total net discount during the bin site storage period was computed from these individual discount figures. In the case of local sales and other instances where selling price rather than grade factors were given on the county ASC forms, the difference between selling price and the No. 2 price for the same day and market was used.

The shrinkage due to unaccountable loss in weight during the storage period for each bin site was obtained by comparing the total bushels weighed into the bin site with the total bushels weighed out of the bin site. Records were complete since all of the 1948, 1949, and 1950 corn had been moved out of the bin sites at the time the study was made. Completely deteriorated corn, such as that in bin tops or next to bin leaks, which was removed from bins during the storage period and hauled to the dump was weighed out and recorded on individual bin site records. Such completely deteriorated corn was classified as shrinkage, rather than quality deterioration, for comparability with the shrinkage figures obtained in the elevator phase of the study.[12] Both types of shrinkage were converted to dollar values by multiplying the bushels of shrinkage by the uniform price of $1.44 per bushel, which was the average value of the corn stored in the elevators over the same period.

Storage volume and length of storage

The total storage volume of bushels received at bin sites in each of the 10 sample counties is shown in table 11. The total bushels received for the 95 bin sites was 18,314,390, varying by county from 268,828 bushels for the 3 bin sites in county number 10 to 4,172,781 bushels for the 20 bin sites in county number 6. The corresponding total number of bushels moved out is shown in the next column. These county totals varied in a similar fashion and totaled 18,033,722 bushels for the 10 counties. The amount of corn moved out, as shown in this column, is the number of bushels of saleable corn and does not include spoiled corn hauled to the dump. The total shrinkage is the difference between bushels of corn received and the quantity of corn moved out or on hand.[13] The last column of table 11 shows the total bushel years of corn stored. These figures were obtained by multiplying the number of bushels stored times the number of months the corn was in storage and dividing this product by 12.[14] The total bushel years of storage was 53,336,638; the totals by county varied from 652,017 for county 10, to 14,326,105 in county 6.

Table 11.--Bushels of corn received and moved out, total shrinkage and bushel years stored of reserve stocks of 1948, 1949 and 1950 corn stored in binsites of 10 Iowa counties

County number	Number of bin sites in the county	Amount of 1948, 1949 and 1950 corn received	Amount of 1948, 1949 and 1950 corn moved out or on hand	Total shrinkage	Total bushel years of corn stored
		Bushels	*Bushels*	*Bushels*	*Bushels*
1................	11	2,704,434	2,674,535	29,899	6,624,039
2................	10	2,987,365	2,920,581	66,784	8,040,555
3................	15	1,669,313	1,640,543	28,770	5,481,565
4................	9	1,114,886	1,103,774	11,112	3,195,829
5................	10	2,212,466	2,177,719	34,747	7,035,922
6................	20	4,172,781	4,105,377	67,404	14,326,105
7................	7	1,123,520	1,104,511	19,009	2,767,957
8................	4	988,650	976,523	12,127	1,159,760
9................	6	1,072,147	1,063,259	8,888	3,132,148
10...............	3	268,828	266,900	1,928	652,017
Total............	95	18,314,390	18,033,722	280,668	53,336,638

The storage volume (total bushels received) varied among the individual bin sites from 8,624 bushels for one bin site in county 10, to 690,923 bushels for one bin site in county 2. The individual bin site figures for total bushels moved out and total shrinkage varied accordingly. The individual bushel years of storage by bin site varied from 13,673 to 2,204,301. Fourteen of the bin sites had over 1,000,000 bushel years of storage, 27 had from 500,000 to 1,000,000, 28 had from 250,000 to 500,000, and 26 had less than 250,000 bushel years of storage.

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[12] Completely deteriorated corn is not included with outgoing shipments from elevator storage, but instead, appears as a part of the total shrinkage.

[13] Only one county of the sample had any old corn on hand May 1, 1955. According to the inventory records this amounted to 265,125 bushels of 1951 Grade 2 corn which was only 6.4 percent of the total corn received. This volume was checked by measurement and the grade was checked by sampling. Since this corn graded No. 2 or better, no deterioration was computed on it.

[14] The last step is necessary in order to convert bushel months into bushel years.

Table 12 shows the average storage period and the dates of the first and last receipt into and shipment from bin site storage in the 10 sample counties. The average storage period, shown in the third column, varied from 1.17 years to 3.78 years and averaged 2.91 years in the 10 counties. In most of the counties the first 1948 corn was received in September 1949, and in many cases the last 1950 corn was not received until late fall of 1952. The first shipments of this corn from bin sites were made in the winter of 1949-1950 and shipment was not completed until the fall and winter of 1954-1955. The first of the corn received at any of the counties was in September 1949 and the last shipment from the 10 counties was in January 1955.

Table 12.--Average storage period and dates of first in and last out of 1948, 1949 and 1950 corn stored in bin sites of 10 Iowa counties

County number	Number of bin sites in county	Average years in storage	Date of		Date of	
			First receipt (mo.-yr.)	Last receipt (mo.-yr.)	First shipment (mo.-yr.)	Last shipment (mo.-yr.)
1...........	11	2.45	9 - 49	12 - 52	1 - 50	7 - 54
2...........	10	2.69	9 - 49	11 - 52	10 - 49	1 - 55
3...........	15	3.28	9 - 49	9 - 52	1 - 50	1 - 55
4...........	9	2.87	9 - 49	12 - 51	1 - 50	7 - 54
5...........	10	3.18	9 - 49	11 - 51	1 - 50	7 - 54
6...........	20	3.43	9 - 49	11 - 52	10 - 49	1 - 55
7...........	7	2.46	11 - 49	12 - 51	1 - 50	7 - 54
8...........	4	1.17	11 - 49	11 - 52	1 - 50	7 - 54
9...........	6	3.78	9 - 49	9 - 52	10 - 49	7 - 54
10..........	3	2.43	9 - 49	10 - 52	1 - 50	7 - 54
Average.....		2.91	9 - 49	12 - 52	10 - 49	1 - 55

Shrinkage

Table 13 summarizes in physical terms the shrinkage of reserve stocks of corn stored at bin sites in the 10 sample counties. It shows shrinkage which was due to unaccountable reduction in volume, as well as the corn which was completely deteriorated and classed as shrinkage rather than deterioration. (This makes shrinkage figures at bin sites comparable to those at elevators.) Shrinkage due to uncounted reduction in volume totaled 239,828 bushels, while that due to completely deteriorated corn amounted to 40,840 bushels for the 95 bin sites in the 10 counties. The combined losses varied from 1,928 bushels for the bin sites in county 10 to 67,404 bushels for the bin sites in county 6, and totaled 280,668 bushels for all bin sites.

The average total shrinkage per bushel received varied considerably by county, ranging from 0.72 percent for the bin sites in county 10 to 2.24 percent for the bin sites in county 2. The over-all average for the 10 counties was 1.53 percent. Total shrinkage as a percent of the bushel years stored is one of the most useful measures available for comparing different types and sizes of storage structures when the average length of storage is unequal. These figures ranged from 0.22 percent for the bin sites in county 9 to 1.05 percent for those in county 8. The over-all average per bushel year shrinkage was slightly over one-half percent (0. 53).

The physical shrinkage by individual bin site varied even more than the county averages would indicate. Two bin sites, one in county 4 and one in county 6 had an unaccountable gain rather than reduction in volume of 12,980 bushels. Forty-three of the bin sites showed no shrinkage from completely deteriorated corn, but the highest shrinkage from this source amounted to 13,112 bushels. The total shrinkage varied from a high of 26,092 to a low of 23 bushels.

Table 13.--Shrinkage in reserve stocks of 1948, 1949 and 1950 corn stored in bin sites of 10 Iowa counties

County number	Shrinkage due to		Total shrinkage	Total shrinkage as percent of	
	Unaccounted reduction in volume	Corn completely deteriorated		Bushels received	Bushel years stored
	Bushels	*Bushels*	*Bushels*	*Percent*	*Percent*
1............	27,899	2,000	29,899	1.11	0.45
2............	48,528	18,256	66,784	2.24	0.83
3............	26,506	2,264	28,770	1.72	0.52
4............	9,260	1,852	11,112	1.00	0.35
5............	26,465	8,282	34,747	1.57	0.49
6............	65,333	2,071	67,404	1.62	0.47
7............	17,061	1,948	19,009	1.69	0.69
8............	11,257	870	12,127	1.23	1.05
9............	6,778	2,110	8,888	0.83	0.22
10...........	741	1,187	1,928	0.72	0.30
Total........	239,828	40,840	280,668	13.73	5.37
Weighted average....	---	---	---	1.53	0.53

The total shrinkage per bushel stored varied from 0.08 percent for one bin site in county 6, to 3.78 percent for a bin in county 2. This shrinkage figure was less than one percent for 24 of the bin sites, between 1-1/2 percent for 20 bin sites, between 1-1/2 and 2 percent for 32 bin sites, between 2 and 2-1/2 percent for 13 bin sites, between 2-1/2 and 3 percent for 4 bin sites, and over 3 percent per bushel stored for 2 of the bin sites. The total shrinkage per bushel year of storage varied from 0.03 percent to 4.30 percent. This figure amounted to less than 0.25 percent for 13 bin sites, between 0.25 and 0.5 percent for 33 bin sites, between 0.5 and 0.75 percent for 34 bin sites, between 0.75 and 1.00 percent for 7 bin sites, between 1.0 and 1.5 percent for 6 bin sites, and over 1.5 percent for 6 of the individual bin sites.

The decrease in value due to completely deteriorated corn and decrease in value due to unaccountable loss in volume were obtained (table 14) by multiplying shrinkage shown in the corresponding columns of table 13 by an average value of $1.44 per bushel. Values vary among counties, as do the corresponding physical shrinkage figures discussed above. For all 95 bin sites, the total decrease in value due to unaccountable loss in volume was $345,353 and the total decrease in value due to completely deteriorated corn was $58,809. The decrease in value from both categories totaled $404,162.

The average value of total shrinkage per bushel received varied by counties from 1.03 cents to 3.22 cents, and averaged 2.21 cents for the bin sites in all 10 counties. The average value of total shrinkage per bushel year of storage varied from 0.31 cent in county 9 to 1.51 cents in county 8. The over-all average was about 3/4 cent (0.70) per bushel per year for the 10 sample counties.

The value of shrinkage per bushel received varied among the individual bin sites from zero to 5.44 cents. These figures amounted to less than one cent for 13 bin sites, from 1 to 2 cents for 27 bin sites, from 2 to 3 cents for 40 bin sites, from 3 to 4 cents for 4 bin sites, and over 4 cents for 5 of the bin sites. The value of shrinkage per bushel year of storage varied from zero to 6.19 cents. The shrinkage per bushel year of storage came to less than 0.5 cent for 27 bin sites, to between 0.5 and 1.0 cent for 46 bin sites, to between 1.0 and 1.5 cents for 16 bin sites, and over 1.5 cents for 4 of the bin sites.

Table 14.--Value of shrinkage in reserve stocks of 1948, 1949, and 1950 corn stored in bin sites of 10 Iowa counties. Value of the stored corn was established at $1.44 per bushel

County number	Decrease in value due to		Total	Value of shrinkage	
	Unaccounted deduction in volume	Completely deteriorated corn		Per bushel received	Per year of corn stored
	Dollars	*Dollars*	*Dollars*	*Cents*	*Cents*
1	40,175	2,880	43,055	1.59	0.65
2	69,880	26,289	96,169	3.22	1.20
3	38,169	3,260	41,429	2.48	0.76
4	13,334	2,667	16,001	1.43	0.50
5	38,110	11,926	50,036	2.26	0.71
6	94,080	2,982	97,062	2.33	0.68
7	24,568	2,805	27,373	2.44	0.99
8	16,210	1,253	17,463	1.77	1.51
9	9,760	3,038	12,798	1.19	0.31
10	1,067	1,709	2,776	1.03	0.43
Total	345,353	58,809	404,162	19.74	7.74
Weighted average	---	---	---	2.21	0.76

Quality deterioration

Deterioration in quality of stored corn at bin sites in the 10 sample counties was summarized (table 15). Total discounts on corn shipped was obtained for the bin sites in each county by adding the products of the discounts per bushel of corn shipped multiplied by the bushels shipped in each lot (column 4). Similarly, discounts on corn received is the sum of the products of discounts on corn received multiplied by the bushels received. The net value of deterioration of corn while in storage shown in the last column is the difference between the total quality discount on the corn when shipped from storage and the total quality discount on the corn when received for storage. The total discounts on corn shipped and on corn received varied widely by counties. The total net value of deterioration while in bin site storage ranged from $4,144 in county 10 to $170,099 in county 2, and totaled $653,433 for the 95 bin sites.

The total discounts on corn shipped varied among the individual bin sites from zero for one bin site in county 10 to $43,444 for a bin site in county 2. Twelve of the bin sites had no discounts on corn received. The highest total discount on bushels received was $1,121 for a bin site in county 9. The total net value of deterioration while in storage varied from zero for one bin site to $43,326 for the bin site with the highest total decrease in market value.

Table 16 shows the average quality discounts per bushel received for storage, and per bushel year of storage, for the bin sites in the 10 counties. Discounts on shipments per bushel received averaged 3.67 cents for the 10 counties. The average discounts on receipts per bushel received averaged 0.1 cent for the 10 counties. The average net value of deterioration while in storage varied from 1.26 cents in county number 1 to 5.69 cents in county number 2, and averaged 3.57 cents for the 10 counties.

The average discount per bushel year of storage on shipments averaged 1.26 cents for all 10 counties. The average discount per bushel year of storage on receipts averaged 0.03 cent for the 10 counties. The difference, which is the average net value of deterioration per bushel year while in storage, averaged 1.23 cents for the 10 counties.

Table 15.--Deterioration in reserve stocks of 1948, 1949, and 1950 corn stored in bin sites of 10 Iowa counties

County number	Number of bin sites in county	Quantity of corn received	Total discounts		Net value of deterioration of corn while stored in bin sites
			On corn shipped	On corn received	
		Bushels	*Dollars*	*Dollars*	*Dollars*
1...........	11	2,704,434	39,628	5,616	34,012
2...........	10	2,987,365	171,311	1,212	170,099
3...........	15	1,669	78,829	3,319	75,510
4...........	9	1,114,886	47,550	1,448	46,102
5...........	10	2,212,466	115,683	1,160	114,523
6...........	20	4,172,781	125,802	2,659	123,143
7...........	7	1,123,520	40,473	98	40,375
8...........	4	988,650	14,220	471	13,799
9...........	6	1,072,147	34,029	2,303	31,726
10..........	3	268,828	4,426	282	4,144
Total.......	95	18,314,390	672,001	18,568	653,433

Table 16.--Discounts on shipments and receipts and net value of deterioration per bushel receipts and per bushel year of 1948, 1949, and 1950 corn stored in bin sites of 10 Iowa counties

County number	Discount on shipments per bushel received	Discount on receipts per bushel received	Net value of deterioration in storage per bushel received	Discount on shipments per bushel per year of corn stored	Discount on receipts per bushel per year of corn stored	Net value of deterioration in storage per bushel per year of corn stored
	Cents	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
1.........	1.45	0.21	1.26	0.60	0.08	0.51
2.........	5.73	0.04	5.69	2.13	0.02	2.12
3.........	4.72	0.20	4.52	1.44	0.06	1.38
4.........	4.27	0.13	4.14	1.49	0.05	1.44
5.........	5.23	0.05	5.18	1.64	0.02	1.63
6.........	3.01	0.06	2.95	0.88	0.02	0.86
7.........	3.60	0.01	3.59	1.46	0.004	1.46
8.........	1.44	0.05	1.40	1.23	0.04	1.19
9.........	3.17	0.21	2.96	0.84	0.06	0.78
10........	1.65	0.10	1.54	0.68	0.04	0.64
Total.....	34.27	0.94	33.23	12.39	1.394	12.01
Weighted average.	3.67	0.10	3.57	1.26	0.03	1.23

The discount per bushel stored on corn shipped varied among the individual bin sites from zero to 38.04 cents. The highest discount per bushel stored on corn received was 0.38 cent for one bin site in county 3. The net value of deterioration per bushel stored over the entire storage period also varied from zero to 38.04 cents. This figure amounted to less than one percent of 15 bin sites, between 1 and 2 cents for 16 bin sites, between 2 and 3 cents for 20 bin sites, between 3 and 4 cents for 12 bin sites, between 4 and 5 cents for 13 bin sites, and over 5 cents per bushel for 19 of the bin sites.

The discount per bushel year of storage on shipments varied from zero to 12.28 cents. This discount on receipts varied from zero for 13 bin sites[15] to 0.33 cent for 1 bin site in county 2. The total value of quality deterioration per bushel year of storage amounted to less than one-half cent for 18 bin sites, from one-half to 1 cent for 31 bin sites, from 1 to 1-1/2 cents for 20 bin sites, from 1-1/2 to 2 cents for 15 bin sites, from 2 to 3 cents for 7 bin sites, and to more than 3 cents for only 3 of the bin sites.

Total decrease in value of stored corn

In order to give a picture of the total decrease in value of 1948, 1949, and 1950 corn in storage in the 10 sample counties, the decrease in value due to shrinkage and to deterioration is summarized by county (table 17). This total value of quality deterioration and shrinkage varied from $6,920 in county 10 to $266,268 in county 2, and totaled $1,057,595 for the 10 counties.

The average total value of shrinkage and quality deterioration per bushel stored was obtained for each county by dividing the total value figures by the total bushels received at the bin sites in each county. They varied from 2.57 cents in county 10 to 8.91 cents in county 2, and averaged 5.77 cents for all 95 bin sites in the 10 counties (table 17). The average total value of quality deterioration and shrinkage per bushel year of storage shown in the last column was obtained by weighting the total value figures by the total bushel years of storage for the bin sites in each of the 10 counties. This figure varied from 1.06 cents in county 10 to 3.31 cents in county 2, and averaged 1.98 cents for all the bin sites in the 10 sample counties.

The total dollar value of quality deterioration and shrinkage varied among the individual bin sites from $33 for one bin site in county 10 to $80,899 for a bin site in county 2. The total value of quality deterioration and shrinkage per bushel stored varied from 0.38 cent for each of 2 bin sites in county 7, to 41.10 cents for a bin site in county 2. This total decrease in market value over the entire storage period amounted to less than 2 cents per bushel for 8 bin sites, from 2 to 3 cents per bushel for 10 bin sites, from 3 to 4 cents per bushel for 13 bin sites, from 4 to 5 cents per bushel for 16 bin sites, from 5 to 6 cents per bushel for 14 bin sites, from 6 to 7 cents per bushel for 11 bin sites, from 7 to 9 cents per bushel for 11 bin sites, and over 9 cents per bushel for 12 of the bin sites.

The total cost of quality deterioration and shrinkage per bushel year of storage varied among the individual bin sites from 0.24 cent to 13.27 cents. This total decrease in market value per bushel year of storage amounted to less than one cent for 11 bin sites, between 1 and 2 cents for 51 bin sites, between 2 and 3 cents for 22 bin sites, between 3 and 4 cents for 5 bin sites, and over 4 cents for 6 of the individual bin sites.

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[15] One bin site in county 5 had a total discount on receipts of $8, but this was less than 0.01 cents both on the per bushel stored basis and on the basis of bushel years of storage.

Table 17.--Value of deterioration and shrinkage of 1948, 1949 and 1950 corn stored in bin sites of 10 Iowa counties

County number	Decrease in value due to		Net value of deterioration of corn in storage	Sum of net deterioration plus value of total shrinkage	Value of deterioration and shrinkage	
	Unaccountable loss in volume	Completely deteriorated corn			Per bushel received	Per bushel per year stored
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Cents*	*Cents*
1..............	40,175	2,880	34,012	77,067	2.85	1.16
2..............	69,880	26,289	170,099	266,268	8.91	3.31
3..............	38,169	3,260	75,510	116,939	7.01	2.13
4..............	13,334	2,667	46,102	62,103	5.57	1.94
5..............	38,110	11,926	114,523	164,559	7.43	2.34
6..............	94,080	2,982	123,143	220,205	5.28	1.54
7..............	24,568	2,805	40,375	67,748	6.03	2.45
8..............	16,210	1,253	13,799	31,262	3.16	2.70
9..............	9,760	3,038	31,726	44,524	4.15	1.10
10.............	1,067	1,709	4,144	6,920	2.57	1.06
Total	345,353	58,809	653,433	1,057,595	52.96	19.73
Weighted average	---	---	---	---	5.77	1.98

Relation of costs of quality deterioration and shrinkage per bushel year of storage to management index, length of storage and bushels stored

Just as was assumed in the study of losses which occur in country elevator storage, loss in market value attributable to physical changes in corn stored at bin sites is assumed to be partially dependent on management of the stored corn, length of storage period, and size of the storage facilities. Considerable variation was observed among the 94[16] bin sites with respect to each of these three factors as well as with respect to loss in market value during storage. Multiple regression analysis was used to examine the relationships between these factors and the loss in market value. Two different linear multiple regression equations were used for this purpose. (See appendix B). In one, the observed total annual per bushel loss in market value from shrinkage plus that from quality deterioration was taken as a function of the observed management index,[17] length of storage and bushels of corn stored in each of the 94 bin sites. Although the equation explained only 9 percent of the variation in the observed total annual per bushel cost of quality deterioration plus shrinkage, the results were statistically significant at the .05 probability level. In the other equation, the observed annual per bushel loss in market value from shrinkage alone was taken as a function of the same three variables. This equation explained 22 percent of the variation in the observed annual per bushel loss in market value from shrinkage alone, and the results were statistically significant at the .01 probability level.

On the basis of the regression equation, both the total annual per bushel cost of shrinkage plus quality deterioration, and that of shrinkage alone were found to vary inversely with the number of months of storage.[18] This relationship is contrary to the opinion held by many managers of corn storage who believe that after 4 or 5 years of storage it is difficult to avoid losses in stored corn. The results here indicate that the annual per bushel costs of both shrinkage and quality deterioration decrease as the length of storage period increases. However, it should be noted that the corn which first went out of condition was moved out early in the storage period and therefore was stored for a relatively short period. In any case, the results obtained seem quite conclusive in the case of shrinkage alone, and definitely indicative in the case of total annual loss in market value during storage.[19]

While very little positive relationship was observed between the size of the bin site and total annual per bushel cost, there was an indication that these costs may be slightly higher in large bin sites than in the smaller ones.

The relationship between the index of management which was constructed from observed data and the per annual bushel costs of shrinkage alone was found to be substantially different than that between the index and the combined cost of shrinkage and quality deterioration. The costs of shrinkage alone were found to decrease as the management index score increased. The costs of shrinkage plus quality deterioration were found to increase as the management index score increased, and this relationship was found to be statistically significant. Evidently the costs of quality deterioration alone were positively associated with the management score constructed. This may be due to certain factors in the score, such as the number of fumigations, which could be the result of quality trouble rather than management devices used to prevent it.

Quantitatively, the total annual per bushel cost of shrinkage plus quality deterioration was found to

(1) increase about 0.2 cent with each increase of 5 points in the management index,

(2) decrease by about 0.1 cent with each 3-month increase in length of the storage period, and

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[16] One bin site in county number 4 was transferred to another bin site and was not included in this analysis, leaving 94 instead of 95 bin sites.

[17] See appendix A, Index of Storage Management for Bin Sites, for an explanation of the management factors selected for study and values assigned to measure their importance.

[18] In the case of shrinkage costs alone, this relationship is statistically highly significant.

[19] An analysis of the relationship between length of storage period and loss due to quality deterioration is being made.

(3) increase by about 0.25 cent with each 1,000,000 bushel increase in the number of bushels of corn stored at the bin site.[20]

The total annual per bushel cost of shrinkage alone was found to

(1) decrease about 0.01 cent with each increase of 7 points in the management index,

(2) decrease about 0.1 cent with each 3-month increase in the length of the storage period, and

(3) increase by about 0.5 cent with each 1,000,000 increase in the number of bushels of corn stored at the bin site. Of course the cost of shrinkage alone was lower throughout the entire range than the cost of shrinkage plus quality deterioration.[21]

Quality deterioration of 1952 corn

As was true in the case of elevator storage, the technology and understanding of storage management problems have advanced since 1948 corn was originally placed in bin sites. Mechanical aeration has been improved greatly, while residual insecticides, improved fumigants, methods of controlling incoming quality, and temperature and humidity recording equipment have all been developed substantially since that time. In view of this, the costs of quality deterioration might be expected to be less for present long-term corn storage than that incurred in the 1948 and 1949 corn.

Until all of the 1952 corn had been moved from at least a resonable number of bin sites, it is impossible to obtain a representative sample of the 1952 bin site stored corn. For this reason, it is difficult to compare quantitatively the extent of quality deterioration of 1952 corn with the 1948 and 1949 corn stored at bin sites. Present legislation makes it impossible to move sound 1952 corn out of bin sites at market prices below the formula price (which is based on the support price). Under the law, 1952 corn moved out of bin sites must be out-of-condition, or threatening to go out of condition, except under special circumstances such as for aid to disaster farm areas. Therefore, the 1952 corn moved out of bin sites up to the time of this study was probably not representative of the total of that crop stored with respect to the extent of the quality deterioration incurred in the total quantity stored. The 1948, 1949, and 1950 crops are the most recent ones which have been completely removed from bin sites, and for which a representative sample could be obtained.

Subject to these limitations, the quality deterioration figures for the first 2,041,359 bushels of 1952 corn removed from the bin sites in the 10 sample counties are summarized (table 18). No analysis has been made of these figures because of their lack of representativeness. The bushels removed from the sample bin sites varied from 214 bushels from the bin sites in county 10 to 715,714 bushels from the bin sites in county 3. The period for which this corn was stored varied from 8.9 months to 17.7 months and averaged 10.5 months for the 10 counties.

The bushel months of storage for 1952 corn moved out of bin sites were obtained by multiplying the bushels moved out by the average storage period. The corresponding bushel years of storage was obtained by dividing the bushel months of storage by 12. The bushel years of storage varied from 245 to 528,174 and averaged 178,282 for the 10 counties.

The average discount per bushel of the 1952 corn moved out of the bin sites in each of the counties varied from 0.64 cent per bushel in county 4 to 13.3 cents in county number 10, and averaged 2.29 cents for the 10 counties. The average discount per bushel year of storage[22] varied from 0.51 cent to 11.62 cents, and averaged 2.63 cents for the 10 counties.

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[20] This equation was $Y_1 = 2.24 + .0385\ X_1 - .031\ X_2 + .00000025\ X_3$, (see the Statistical Appendix).

[21] This equation was $Y_2 = 1.9108 - .0014\ X_1 = .033\ X_2 + .00000051\ X_3$, (see the Statistical Appendix).

[22] These figures are higher than the average for each bushel moved out in all counties for which the average storage period was less than 12 months.

Table 18.--Cost of quality deterioration of 1952 CCC corn stored in bin sites in 10 Iowa counties (all withdrawals)

County		Quantity moved out	Total discount	Bushel months storage	Bushel years storage	Average storage period	Discount	
Name	No.						Per bushel moved out	Per bushel year
		Bushels	*Dollars*	*Bushels*	*Bushels*	*Months*	*Cents*	*Cents*
Plymouth............	1	158,649	1,546	1,856,006	154,667	11.7	0.97	1.00
Clay................	2	715,714	24,479	6,338,093	528,174	8.9	3.42	4.63
Franklin............	3	401,005	6,797	4,415,093	367,924	11.0	1.70	1.85
Black Hawk..........	4	158,559	1,020	1,581,888	131,824	10.0	0.64	0.77
Shelby..............	5	39,466	2,121	520,877	434,064	13.2	5.38	4.89
Story...............	6	254,201	7,945	3,414,233	284,519	13.9	3.24	2.79
Iowa................	7	9,921	75	175,491	14,624	17.7	0.75	0.51
Clinton.............	8	281,953	2,188	2,806,629	233,886	10.0	0.78	0.94
Union...............	9	30,677	632	282,536	23,545	9.2	2.06	2.69
Monroe..............	10	214	28	2,936	245	13.7	13.30	11.62
Total.............		2,041,359	46,832	21,393,782	1,782,815	10.5*	2.29*	2.63*
Average...........		204,136	4,683	2,139,378	178,282			

* These figures are weighted averages for the 10 counties.

Table 19.--Cost of quality deterioration of 1952 corn stored in bin sites in 10 Iowa counties (loading orders only)

County		Quantity moved out	Total discount	Bushel months storage	Bushel years storage	Average storage period	Discount	
Name	No.						Per bushel moved out	Per bushel year
		Bushels	*Dollars*	*Bushels*	*Bushels*	*Months*	*Cents*	*Cents*
Plymouth............	1	92,497	1,070	1,226,116	102,176	13.3	1.16	1.05
Clay................	2	631,655	14,435	5,679,561	473,297	9.0	2.28	3.05
Franklin............	3	401,005	6,797	4,415,093	367,924	11.0	1.70	1.85
Black Hawk..........	4	158,405	869	1,580,348	131,696	10.0	0.55	0.66
Shelby..............	5	22,824	568	300,000	25,000	13.1	2.49	2.27
Story...............	6	228,779	2,394	3,167,420	263,952	13.8	1.05	0.91
Iowa................	7	3,097	0	52,649	4,387	17.0	0	0
Clinton.............	8	267,973	445	2,681,340	223,445	10.0	0.17	0.20
Union...............	9	25,965	90	231,579	19,298	8.9	0.35	0.47
Monroe..............	10	0	0	0	0	0	0	0
Total.............		1,832,200	26,669	19,334,106	1,611,176	10.6*	1.46*	1.67*
Average...........		203,578	2,963	2,148,234	179,020			

*These figures are weighted averages.

The figures shown in table 18 include local sales of bin tops and other highly deteriorated corn removed from the bins in the normal process of good storage management to maintain the quality of the remaining corn in the bins. While the discounts taken on such corn must be considered a part of the total cost of quality deterioration, they cannot be considered representative of all 1952 corn stored at bin sites. For this reason, small lots of corn sold locally were excluded from the figures shown in table 18, and table 19 was prepared. The latter shows only the shipments of 1952 corn from the bin sites in the 10 sample counties. The columns in table 19 correspond to those in table 18, and each set of figures in the two tables can be directly compared.

The total bushels shipped from bin sites varied from zero to 631,655 bushels and totaled 1,832,200 bushels from the bin sites in all 10 sample counties (table 19). The average storage period of the 1952 corn shipped varied from 8.9 to 17 months and averaged less than a year (10.5 months) for the 10 counties. The bushel years of storage of the 1952 corn shipped averaged 179,020 for the 9 counties with shipments of this corn.

The total discount on the bushels shipped varied from zero in county 10 to $14,435 in county 2, and averaged $2,963 per county for the 9 counties with shipments. The discount per bushel shipped averaged 1.46 cents for the 9 counties. The discount per year of storage per bushel shipped out varied from zero to 3.05 cents and averaged 1.67 cents for the 9 counties shipping out 1952 bin site corn.

This last weighted average figure of 1.67 cents per bushel year of storage of the 1952 corn compares with the weighted average figures of 1.23 cents per bushel year of storage for the1948-1949 corn. As has been pointed out, this in no way indicates that the quality deterioration has been higher on the 1952 corn.

APPENDIX A

Management index for elevators

In addition to obtaining information designed to measure the extent of quality deterioration and shrinkage of CCC-owned corn stored in country elevators, the study was designed to describe and measure the storage management practices for each of the 40 sample elevators. A storage management schedule was obtained for each elevator by personal interview with the elevator manager.

The responses on each of the following management factors were used to obtain a management index score for each elevator:

1. Turning

   The elevator was scored 5 points for each time the grain was turned per year during the storage period.

2. Fumigation

   If the bin(s) was fumigated, the dates, type of fumigant and method of application for each fumigation were obtained, and the elevator was given 5 points for each fumigation during the entire storage period. No attempt was made to refine the fumigation score on the basis of the dates the fumigation was done, the type of fumigant used, the method of application used, the method of application, or the manager's estimate of the successfulness of the fumigation.

3. Visual inspections

   Elevators were given 5 points for each inspection per month on the average over the storage period. No attempt was made to refine this score on the basis of the method of inspection used.

4. Raking

   Methods and frequency of raking the surface of the corn in the bins were obtained. Elevators were given 5 points for each raking per month on the average over the storage period. No attempt was made to refine the raking score on the basis of the method of raking used.

5. Distributing baffle

   If a distributing baffle was used under the downspout when the bins were filled, the elevators were scored 5 points.

6. Temperature determined

   If equipment was used for reading the temperatures of the corn in storage the elevators were scored 5 points. No attempt was made to refine the score on the basis of the type of equipment used nor on the method of using it.

7. Aeration

   The question was asked, "did the bin(s) have aeration equipment? If yes, describe." If the answer was "yes" for the bins holding 25 percent or more of the CCC-owned corn stored in the elevator, a score of 5 was given. Otherwise, the elevator was scored zero. No attempt was made to refine the score on the basis of the percent of total grain aerated, the type of aerating equipment, nor the way the equipment was operated.

8. Grain cleaned and dried

If the corn was cleaned and/or dried at the time it was received, or at any time during the storage period, 5 points were scored for the elevator. No attempt was made to refine the score on the basis of the method of cleaning or drying used.

9. Residual Insecticide

If bins were sprayed with a residual insecticide before putting in corn, the elevators were scored 5 points.

The scores on each of these 9 management factors were weighted equally to arrive at the total management index score for each of the 40 elevators in the sample. The management index for each elevator is the sum of the points earned for each management factor.

The average management scores and the average total management index for the elevators in each structure group are shown in table 20. The overall averages shown in the last line of the table are weighted by the number of elevators in each classification.

The total management index was lowest (37.77 points) for the flat steel elevators and highest (51.15) for the wood elevators. The average for the concrete elevators was 49.60, and that for the steel tank elevators was 44.00. The average management index for all the elevators was 46.75.

The management practices scores and the total management index for the individual elevators varied considerably. On the turning score, 13 of the elevators scored zero, 23 scored 5, 3 scored 10, and 1 scored 20 points. On the fumigation score, 5 scored zero, 10 scored 5, 12 scored 10, 12 scored 15, and 1 scored 20 points. On the inspection score, 1 of the elevators scored zero, 9 scored 5, 6 scored 10, 2 scored 15, 17 scored 20, 2 scored 25, 1 scored 35, and 2 scored 40 points. On the raking score, 5 scored zero, 21 scored 5, 2 scored 10, 1 scored 15, 9 scored 20, 1 scored 25, and 1 scored 60 points. On the baffle plate score, 32 of the elevators scored zero, and only 8 scored 5. On the temperature reading equipment score, 30 scored zero and 10 scored 5 points. On the aeration score, only 1, a flat steel elevator, scored 5 points. All the rest scored zero. On the cleaning and drying score, 34 of the elevators scored zero and the other 6 scored 5 points. On the residual insecticide score, only 7 of the elevators scored zero--the other 33 scored 5 points.

On the total management index, 7 of the elevators scored 25 points, 3 scored 30, 3 scored 35, 4 scored 40, 6 scored 45, 1 scored 50, 6 scored 55, 3 scored 60, 3 scored 65, 3 scored 70, and 1 wood elevator scored 105 points. None scored less than 25 points.

Management index for bin sites

An index of storage management was designed to evaluate the usefulness of various storage management factors at bin sites. Selection of the factors and the values assigned to measure their importance is subjective, but the choice was made after considering the procedures which storage managers believe give the greatest protection to stored grain.

A storage management schedule was obtained for each bin site by personal interview with county ASC officials administering the bin site storage program. The responses on the following management factors were used for obtaining the management index score for each bin site.

1. Aeration

If the bin(s) storing 25 percent or more of the corn in the bin site had aeration equipment, a score of 5 was given. Otherwise, a score of zero was given to the bin site. No attempt was made to refine the score on the basis of the percent of total grain aerated in each bin site, the type of aeration equipment, or the way the aeration equipment was operated.

Table 20.--Average management factor scores and total management index by types of construction of 1948 corn stored in 40 country elevators of Iowa

Type of construction	Number of times				Baffle plate used	Temperature determined	Aeration	Grain was cleaned or dried	Residual insecticide used	Management index
	Corn was turned	Grain was fumigated	Inspection per month	Raked per month						
Concrete elevator......	5.00	8.08	17.31	10.77	1.15	2.31	0	1.15	3.85	49.60
Wood elevator..........	5.77	9.62	18.46	11.54	0.77	0	0	.38	4.61	51.15
Flat steel.............	1.11	10.55	10.00	7.78	1.11	1.67	.56	.56	4.44	37.77
Steel tanks............	3.00	9.00	17.00	9.00	1.00	1.00	0	1.00	3.00	44.00
Weighted average.......	4.13	9.25	16.00	10.13	1.00	1.25	.13	.75	4.12	46.75

2. Distributing baffle

   If a distributing baffle was used under the downspout when the bins were filled, 5 points were given to the bin site.

3. Residual insecticide

   If the bins were sprayed with a residual insecticide before putting in corn, the bin sites were scored 5 points.

4. Fumigation

   If the bin(s) were fumigated, the bin site was given 5 points for each fumigation during the entire storage period. No attempt was made to refine the fumigation score on the basis of the dates the fumigation was done, the type of fumigant used, the method of application or the bin site manager's estimate of the successfulness of the fumigation.

5. Visual inspection

   Bin sites were given 5 points for each inspection per month on the average over the storage period. No attempt was made to refine this score on the basis of the method of inspection used.

6. Raking

   If the surface of the grain in the bins was raked, bin sites were given 5 points for each raking per month on the average over the storage period.

The score on each of these 6 storage management factors was weighted equally to arrive at the total management index score for each of the 95 bin sites in the sample. The management index for each bin site is the sum of the points earned for each management factor for that bin site.

The average management scores and the average total management index for the bin sites in each of the 10 counties are shown in table 21. The average aeration score varied from zero for the bin sites in 3 counties to 3.00 points for the bin sites in county number 2. The aeration score averaged 1.26 for the 95 bin sites. The average score on use of a baffle when the bins were filled varied from zero in 4 counties to 5.00 in county number 10. This score averaged 1.21 for the bin sites in the 10 counties. Bins were sprayed with a residual insecticide before filling in only 2 counties, and the average score was 0.16 for the bin sites in all 10 counties.

The average fumigation score varied from 3.57 points to 14.00 and averaged 7.05 for the 95 bin sites. The average inspections per month score varied from 3.00 to 13.50. It was 5.00 points in 5 of the counties and averaged 6.47 for all 10 counties. The average rakings per month score varied from 3.58 to 10.00 and averaged 6.05 for all 10 counties.

The weighted average total management index for the 95 bin sites in the 10 counties was 22.21. Three counties had a score between 12 and 15 points, 1 had 18.33, and 4 scored between 21 and 25. The two highest counties averaged 37.5 and 40 points.

Considerable variation existed among the individual bin sites, both on the management factor scores and the total management index. Seventy-one of the bin sites had aeration equipment for less than 25 percent of the grain stored there, while 24 had aeration equipment for 25 percent or more of the total corn stored and scored 5 points on the aeration question. A baffle was used under the downspout to distribute the corn as the bins were filled at 23 of the bin sites. They were scored 5 points on this question. The remaining 72 were scored zero. The bins at only 3 of the bin sites were sprayed with a residual insecticide before the corn was placed in storage. They received a score of 5 on this question, while the remaining 92 bin sites received a score of zero.

Table 21.--Average management factor scores and total management index by counties of 1948 corn stored in bin sites of Iowa

County number	Aeration yes - 5 no - 0	Baffle used yes - 5 no - 0	Residual insecticide used yes-5; no-0	Number of fumigations per month (x 5)	Number of inspections per month (x 5)	Number of times raked per month (x 5)	Management index
1..................	2.73	4.54	0	5.00	5.00	5.00	22.27
2..................	3.00	0	0	14.00	13.50	9.50	40.00
3..................	1.33	0.33	0	3.66	9.67	9.67	24.66
4..................	1.11	0	1.11	7.22	4.44	4.44	18.33
5..................	1.00	0	0	10.50	5.00	5.00	21.50
6..................	0	1.25	0	4.75	3.00	3.75	12.75
7..................	0.71	1.43	0.71	3.57	5.00	3.58	15.00
8..................	0	0	0	5.00	5.00	3.75	13.75
9..................	2.50	1.67	0	13.33	10.00	10.00	37.50
10.................	0	5.00	0	10.00	5.00	5.00	25.00
Weighted average....	1.26	1.21	.16	7.05	6.47	6.05	22.21

Fifteen of the bin sites were not fumigated at all during the storage period and received a score of zero. Forty-six of the bin sites were fumigated once during the storage period and received a score of 5. Fourteen bin sites were fumigated twice during the storage period and received a score of 10. Twenty of the bin sites were fumigated 3 times over the total storage period and received a fumigation score of 15. The corn stored at 9 of the bin sites was inspected less often than once per month and these bin sites were scored zero on this question. Inspections of 56 of the bin sites averaged 1 per month, and these bin sites were scored 5 points. Inspections at 23 of the bin sites averaged twice per month, earning a score of 10 points for these bin sites. Seven of the bin sites earned an inspection score of 15 points because the corn in these bin sites was inspected an average of 3 times per month. The bin tops at 13 of the bin sites were raked less often than once a month so that these bin sites received a score of zero. Fifty-three of the bin sites used raking an average of once per month and received a score of 5. Twenty-six used raking an average of twice per month and received a score of 10. Two bin sites used raking an average of twice per month and received a score of 15. For 1 bin site in county number 6 the bin tops were raked an average of 4 times per month, and this bin site was scored 20 on the raking question.

The total management index varied from 5 to 50 points. Five of the bin sites received a total management index score of 5, 11 received an index of 10, 20 an index of 15, 16 an index of 15, 16 an index of 20, 6 an index of 35, and 9 an index of 40. Two bin sites, both in county number 2, had a total management index score of over 40. Bin site number 191 had an index of 45, and bin site number 192 had a management index of 50.

APPENDIX B

Statistical analysis for elevators

The country elevator storage data for the 1948, 1949, and 1950 corn were examined statistically to measure the relationships of the loss in market value during storage to the management index, the length of the storage period and the number of bushels stored. The following linear multiple regression models were used:

(1) $Y_1 = b_0 + b_1X_1 + b_2X_2 + b_3X_3$

(2) $Y_2 = b_0 + b_1X_1 + b_2X_2 + b_3X_3$, where

Y_1 = cost of shrinkage plus quality deterioration per bushel year of storage, coded by multiplying by 100.

Y_2 = cost of shrinkage per bushel year of storage, coded by multiplying by 100.

X_1 = management index.

X_2 = months of storage, coded by multiplying by 10.

X_3 = bushels stored, coded by dividing by 10.

Using these equations as models the B parameters in two multiple regression equations were estimated by the method of least squares from the elevator storage data for the 1948, 1949, and 1950 corn obtained from the sample. The data used were the storage data obtained for each individual elevator in the sample. Both the Y_1 and Y_2 regression equations were determined only for the entire 40 elevators. No regression equations were computed by structural group.

The resulting regression equations were:

(3) $Y_1 = 692.8385 - 6.0579\ X_1 - .7936\ X_2 + .001036\ X_3\ .R^2 = .41$

(4) $Y_2 = 260.8249 - 1.0382\ X_1 - .4028\ X_2 - .000164\ X_3.\ R^2 = .23$

The multiple correlation coefficients (R's) were 0.64 for equation (3) and 0.48 for equation (4). An R of 0.44 is significant at the .05 probability level and an R of 0.517 is significant at the .01 probability level in this case.[23]

The standard errors for the partial regression coefficients are as follows:

For equation (3)		For equation (4)	
$b_1 = 6.06^{**}$	$s_{b1} = 2.05$	$b_1 = 1.04^{**}$	$s_{b1} = .41$
$b_2 = .79$	$s_{b2} = .59$	$b_2 = .40^{**}$	$s_{b2} = .18$
$b_3 = .001$	$s_{b3} = .003$	$b_3 = .0002$	$s_{b3} = .0006$

In equation (3), b_1 is significant at the .01 probability level and in equation (4) b_1 and b_2 are significant at the .01 probability level. The other partial regression coefficients are not significant.[24]

The simple correlation coefficients (r's) among the variables in equations (3) and (4) are shown in the table below:

	X_1	X_2	X_3	Y_1	Y_2
X_1	1	-.02	.31	-.44	-.44
X_2		1	.20	-.18	-.45
X_3			1	-.13	-.26
Y_1				1	xxx
Y_2					1

Multiple regression equations (3) and (4) are based on coded variables as explained above. However, these equations can be quickly converted so as to apply to the variables when they are not coded. This can be illustrated for equation (3) step by step.

1. The cost of shrinkage plus quality deterioration was multiplied by 100; the equation can be divided by 100,

$$\frac{Y_1}{100} = \frac{692.84}{100} \quad \frac{6.06\ X_1}{100} - \frac{.79\ X_2}{100} + \frac{.001\ X_3}{100}$$

$$Y_{11} = 6.9284 - .0606\ X_1 - .0079\ X_2 + .00001\ X_3$$

2. Y_{11} = cost of shrinkage plus quality deterioration per bushel per year.

   X_1 = the management index (this variable was not coded).

   X_2 = months of storage multiplied by 10; if months of storage is designated by X_{21}, then $X_{21} = 10\ X_2$

   X_3 = bushels stored divided by 10; if bushels stored is designated by X_{31}, then $X_{31} = \frac{X_3}{10}$

Substituting, $Y_{11} = 6.9284 - .0606\ X_1 - .079\ X_{21} + .000001\ X_{31}$

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[23] Snedecor, George W. Statistical Methods. 4th Ed., Iowa State College Press, Ames, Iowa., 1946. p. 351.
[24] The "t" test with 36 degrees of freedom. Ibid., p. 65.

Equation (4) can be restated so as to apply to the variables without coding in exactly the same manner.

Statistical analysis for bin sites

The bin site storage data for the 1948, 1949, and 1950 corn were examined statistically to measure the relationships of the loss in market value during storage to the management index, the length of storage period and the size of the bin site. The following linear multiple regression models were used:

(1) $Y_1 = b_0 + b_1X_1 + b_2X_2 + b_3X_3$

(2) $Y_2 = b_0 + b_1X_1 + b_2X_2 + b_3X_3$, where

Y_1 = cost of shrinkage plus quality deterioration per bushel year of storage, coded by multiplying by 100.

Y_2 = cost of shrinkage per bushel year of storage, coded by multiplying by 100.

X_1 = management index

X_2 = months of storage, coded by multiplying by 10

X_3 = bushels stored, coded by dividing by 10

Using these equations as models the B parameters in two multiple regression equations were estimated by the method of least squares from the bin site storage data for the 1948, 1949, and 1950 corn obtained from the sample. The data used were the storage data obtained for each individual bin site in the 10 sample counties.

Both the Y_1 and Y_2 regression equations were determined only for the 94 bin sites in the 10 sample counties.

The resulting regression equations were:

(3) $Y_1 = 224.3613 + 3.8452\ X_1 - .3074\ X_2 + .00025\ X_3.\quad R^2 = .09$

(4) $Y_2 = 191.0791 - .14\ X_1 - .3324\ X_2 + .00051\ X_3.\quad R^2 = .22$

The multiple correlation coefficients (R's) were .30 for equation (3) and .466 for equation (4). An R of .288 is significant at the .05 probability level and as R of .343 is significant at the .01 probability level in this case.[25]

The standard errors for the partial regression coefficients are as follows:

For equation (3)		For equation (4)	
$b_1 = 3.85^*$	$s_{b1} = 1.58$	$b_1 = -.14$	$s_{b1} = .651$
$b_2 = -.31$	$s_{b2} = .166$	$b_2 = -.33^{**}$	$s_{b2} = .068$
$b_3 = .00025$	$s_{b3} = .00116$	$b_3 = .00051$	$s_{b3} = 2.00477$

In equation (3), b_1 is significant at the .05 probability level and in equation (4), b_2 is significant at the .01 probability level. The other partial regression coefficients are not significant.[26]

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[25] Snedecor, George W. Statistical Methods. 4th ed., Iowa State College Press. Ames, Iowa. 1946. p. 351.

[26] The "t" test with 90 degrees of freedom. Ibid. p. 65.

The simple correlation coefficients (r's) among the variables in equations (3) and (4) are shown in the table below:

	X_1	X_2	X_3	Y_1	Y_2
X_1	1	.107	.206	.235	.048
X_2		1	.045	-.159	-.455
X_3			1	.066	.078
Y_1				1	xxx
Y_2					1

Multiple regression equations (3) and (4) are based on the coded variables as explained above. However, these equations can be quickly converted so as to apply to the variables when they are not coded. This can be illustrated for equation (4) step by step.

1. The cost of shrinkage was multiplied by 100; the equation can be divided by 100,

$$\frac{Y_1}{100} = \frac{191.08}{100} - \frac{.14\ X_1}{100} - \frac{.33\ X_2}{100} + \frac{.00051\ X_3}{100}$$

$$Y_{11} = 1.9108 - .0014\ X_1 - .0033\ X_2 + .0000051\ X_3$$

2. Y_{11} = cost of shrinkage in cents per bushel per year.

X_1 = the management index (this variable was not coded).

X_2 = months of storage multiplied by 10; if months of storage is designated by X_{21}, then $X_{21} = 10\ X_2$

X_3 = bushels stored divided by 10; if bushels stored is designated by X_{31}, then $X_{31} = \frac{X_3}{10}$

Substituting, $Y_{11} = 1.9108 - .0014\ X_1 - .033\ X_{21} + .00000051\ X_{31}$.

Equation (3) can be restated so as to apply to the variables without coding in exactly the same manner.